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EARTHQUAKES

BE PREPARED !

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Publications of the Division also include the Bulletin, Special Report and County Report series, the Geologic Map of California; the Bouguer Gravity Map of California; and other maps and publications. A list of the Division's available publications will be sent upon request. All orders for the California Division of Mines and Geology publications, changes of address, and subscriptions to *California Geology*, should be addressed to P.O Box 2980, Sacramento, California 95812.

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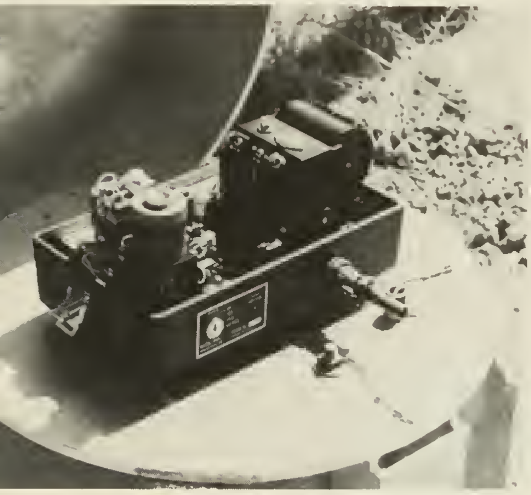
The California Division of Mines and Geology is currently operating three programs that measure movement of the Earth's crust: the strong-motion instrumentation program, the tiltmeter program, and the laser-beam range finder program. Each of the programs measures a different kind of crustal movement.



↑ Strong-motion instruments are called accelerographs and record only when they are triggered by strong earthquake motion. In contrast, a seismograph records continuously, but earthquake motion that triggers an accelerograph drives a seismograph off-scale. The information recorded by accelerographs tells geologists, seismologists, soils engineers, and structural engineers a great deal about the nature of earthquake motion in various geologic environments and how structures react to that earthquake motion.

Gradually accumulating vertical and horizontal strains in the Earth's crust are related to the mountain-building forces that cause earthquakes. Although the strains accumulate gradually, they are sometimes released violently and cause an earthquake. The time and location of earthquakes cannot now be predicted with accuracy; but earth scientists believe that measurement of these strains, when combined with other knowledge of earthquake forces, will someday allow accurate prediction. This slow strain accumulation can be measured by instruments such as tiltmeters and laser-beam range finders.

↑ Tiltmeters are essentially electrolytic bubble levels that are extremely sensitive and record the minuscule *vertical* changes in the attitude of the Earth's crust. Such changes are called crustal tilting.

↑ Laser-beam range finders operate by transmitting an amplitude-modulated narrow beam of light from a mountain peak to a set of prisms on a mountain peak some kilometers away. The light is reflected by the prisms and returns to the transmitting instrument. The time it has taken for the light beam to travel out and back is computed by determining the phase difference between the outgoing and the returning beam. Time-of-travel is then converted to distance. Measurements between mountain tops are repeated regularly, and a change in distance between the two points is the result of *horizontal* strain in the Earth's crust.

For more information about these programs, see the following issues of *California Geology:* accelerographs, July 1972 and January 1973; tiltmeters, July 1972; laser-beam range finders ("geodimeter"), June 1971.

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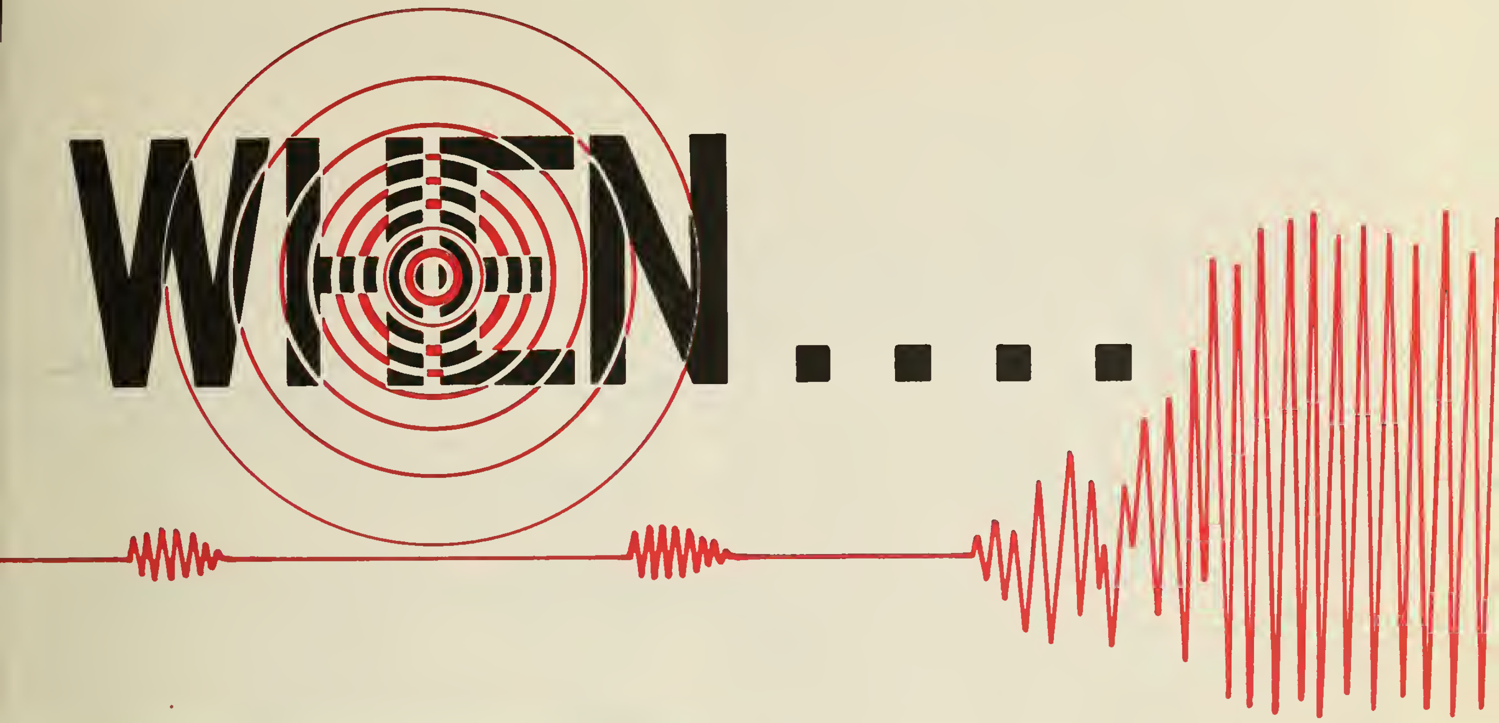


WHEN.... THE EARTHQUAKES ...YOU CAN REDUCE THE DANGER

by William B. Clark and Carl J. Hauge
Geologists,
California Division of Mines and Geology,
Sacramento

FOREWORD

Damaging earthquakes have been and will continue to be part of California's natural environment. It is known with certainty, by repeated precise measurement, that the kinds of deep-seated stresses which caused the Fort Tejon, Owens Valley, San Francisco, Long Beach, Arvin-Tehachapi, and San Fernando earthquakes continue to be exerted within the earth's crust. Knowledgeable earth scientists (who, often as not, take great delight in disputing one another's theories) unanimously agree that California will periodically experience severe earthquakes long into the future.

How often can earthquakes be expected to occur in California? Dr. Robert Wallace, Assistant Chief Geologist, U.S. Geological Survey, Menlo Park, says, with regard to the San Andreas fault alone:

"At the present time we can make only generalized predictions about the occurrence of major earthquakes along the San Andreas fault zone based on past performances of the faults. For example, analysis of the record of seismic activity suggests that two successive magnitude 6 earthquakes somewhere along the San Andreas would occur every 5 years; that the interval for magnitude 7 quakes is 15 years; and that earthquakes of magnitude 8 might be expected at intervals of about 100 years."

And what might be the result of another great earthquake in the San Francisco Bay Area? The report of the California Legislature's Joint Committee for Seismic Safety contains the following scenario outlining the possibilities. "Casualties appear to be extremely heavy. Possibly several hundred have been killed and many thousands injured. The greatest concentration of casualties appears to be in the downtown areas. Medical facilities will face a tremendous overload."

Or in southern California? C. Martin Duke, Professor of Engineering at the University of California at Los Angeles says, "It is distressingly easy to visualize 10,000 deaths."

While fires and floods may often be prevented or controlled, there is no feasible method yet known for heading off a major earthquake. Are we then helpless in the face of calamity? *Not by a long shot!* While we may not be able to prevent an earthquake, there are many positive things which *all* of us can do to prevent or reduce casualties and damages resulting from the quake.

Most earthquake casualties are inflicted in or below structures of one kind or another which are either designed, constructed, or located improperly with respect to the forces to which they are subjected. Anyone who would deliberately attempt to ride out an ocean storm in an improperly designed or constructed ship would be considered foolhardy. Yet here we sit, most of California's communities, in and below many tens of thousands of old structures designed and built with little or no knowledge of earthquake engineering or foundation geology, waiting to ride out a severe earthquake next year or in five years or, with great luck, in twenty years.

The following article outlines some of the things you can do as an individual, as a family, and as a part of your community to improve your odds of coming out of an earthquake intact.

..Wesley G. Bruer, State Geologist

INTRODUCTION

California often is referred to as earthquake country. Earthquakes are part of the state's heritage, and those who reside here must learn to live with them. The historical record of quakes in the state begins with 1769, when Gaspar de Portolá's expedition was shaken by a large earthquake while camped on the Santa Ana River. Few detailed records were kept of earthquakes in California until after 1850 when the state's population began to grow rapidly. By 1900 studies were much more numerous and detailed, and the San Francisco earthquake of 1906 was one of the most widely documented of all. Unfortunately, community leaders attempted to suppress these studies believing that they would be "bad publicity for the community."

California is located on what is known as the "ring of fire", the volcanic belt which roughly coincides with the circum-Pacific seismic belt (see figure 1). This belt curves around the basin occupied by the Pacific Ocean from the coast of Chile, northward along the South American coast through Central America, Mexico, the west coast of the United States, and the southern part of Alaska, through the Aleutian Islands to Japan, the Philippine Islands, New Guinea, the Melanesian Islands, including the Solomons and the Fijis, to the islands of New Zealand. Eighty percent of the world's earthquakes occur along this belt, and all parts of this belt--including California–are jolted by numerous shocks. Other parts of the belt, such as the Aleutian Islands, Japan, and the Melanesian Islands, have more frequent earthquakes than California but, for the past 60 years, destructive earthquakes have occurred in California on the average of about once every two years.

At 0601 on the morning of 9 February 1971, millions of residents of California became acutely aware of the destructive forces of an earthquake. On that morning, the crust of the earth near San Fernando was relieved of some of the stresses that had built up in the rocks over a period of time. For 64 unlucky residents of the area, the ground shaking and subsequent damage to structures resulted in death. Luckier residents suffered no physical injury or only minor injury; however, subsequent events show that virtually everybody who experienced the quake will vividly recall the frightening feeling brought on by the sudden, unexpected, and violent movement of the ground. Aftershocks continued to alarm people for many days.

As terrifying as these movements are, they are clearly to be expected in California. California's location on the circum-Pacific seismic belt assures that it will be shaken again and again by earthquakes as the crust adjusts itself to changing stress. Figures 5 and 6 show that in the conterminous United States, both the number of damaging earthquakes since 1769, and the number of earthquakes during any one year are highest in California.

CAUSES OF EARTHQUAKES

Earthquakes are caused by movement of crustal material as the rocks of the earth adjust to tectonic forces. Recent conclusions derived from the synthesis of geologic data gathered primarily from the world's ocean floors, indicate that the surface of the earth is composed of a number of more or less rigid plates. These plates are "floating" on a "plastic" zone of rock material. The frequency of earthquakes is highest where two plates are being pushed against each other or where one plate is overriding another, both of which occur in the circum-Pacific seismic belt.

The American plate includes both North and South America, and extends from the Mid-Atlantic ridge to the western coast of both of the continents. The San Andreas fault is a part of the western boundary of the American plate, according to some geologists. The crustal material west of the San Andreas fault is a part of the Pacific plate which is moving to the northwest. The stresses built up in the rocks as these plates are pushed into each other are released when the strength of the rock is exceeded, and the result is an earthquake.

TYPES OF FAULTS

Three basic types of fault, based on relative movement, can be identified, and all are known in California. They are called a) a normal fault, in which the hanging wall has moved down relative to the footwall; b) a reverse fault, also called a thrust fault, in which the hanging wall has moved up relative to the footwall; and c) a lateral fault (strike-slip fault), in which the rocks on either side of the fault have moved laterally past each other. (See figure 4).

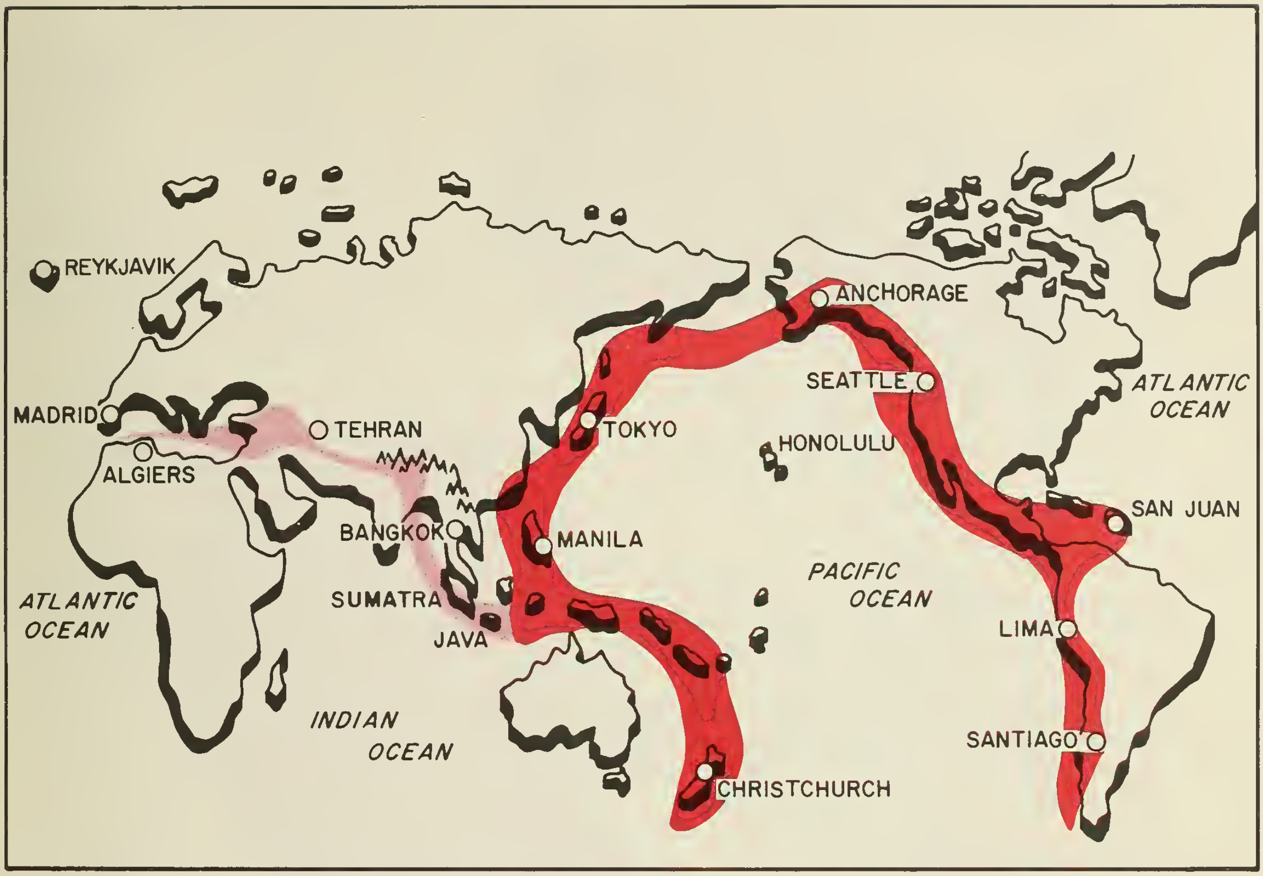


Figure 1. The circum-Pacific seismic belt follows the edge of the Pacific Ocean basin. It is along this belt that 80 percent of the world's earthquakes take place. The Alpide belt extends from Java to Sumatra, through the Himalayas, the Mediterranean, and out into the Atlantic. Seventeen percent of the world's earthquakes strike along this belt. The remaining 3 percent of the world's earthquakes strike along the mid-Atlantic Ridge and elsewhere throughout the world.

In reality, most faults exhibit a combination of vertical and lateral movement, and are called oblique faults. This year's San Fernando earthquake, for example, resulted in measurable fault movement at the ground surface which consisted of a lateral component, during which the rocks moved to the left past each other, and a reverse vertical component. Such a combination of movements is called a "left oblique reverse fault". Thus, the San Gabriel Mountain block moved up, to the left, and out over the San Fernando Valley with a gross movement of as much as seven feet.

Even though many earthquakes are felt by the residents of California each year, they amount to only one one-hundredth of the many thousands of small quakes that are detected instrumentally in the state each year. During 1970 one hundred thirty shocks were felt in California alone, while only one hundred ten were felt in *all* of the other states.

Fortunately, the potentially destructive earthquakes that occur in California do not always strike in areas inhabited by man or in which his structures are located. On 9 February 1971, when the earthquake hit the densely populated San Fernando area, we were unfortunate in the location; but had the quake struck at a different time of day, when schools, offices, and freeways were crowded, the death toll would have been much higher.

The San Fernando earthquake was one of the most devastating in the state's history. Although the magnitude of this temblor was 6.5 on the Richter scale, which ranks it as moderate but not great, a wide and heavily populated area was severely affected. In addition to the 64 deaths caused either directly or indirectly by the earthquake, the damage to property has been estimated to be over $500 million. Subsequent examination of the damage is revealing that the estimates of damage were low, indicating that the cost of the property damage may rise considerably higher.

PREDICTION OF EARTHQUAKES

By collecting data on earthquakes throughout the world, earth scientists are closer to being able to predict earthquakes accurately. Prediction has three parameters: 1) location, 2) magnitude, and 3) time. Crude estimates of the first two can now be made. We know, for example, that earthquakes are going to continue to occur throughout the

Prominent earthquakes in California, 1769 through September 1971 (Intensity VIII and above)

Date	Region	Richter Magnitude	Modified Mercalli Intensity
28 Jul 1769	Orange County, near Irvine	*	
8 Dec 1812	Southern California		VIII-IX
21 Dec	Off coast of southern California		X
10 Jun 1836	Hayward fault, Berkeley		IX-X
Jun 1838	San Francisco region, San Andreas fault		X
10 or 11 Jul 1855	Los Angeles County		VIII
9 Jan 1857	Fort Tejon-Carrizo Plain	Possibly 8	X-XI
26 Nov 1858	San Jose		VIII
Nov 1860	Humboldt Bay		VIII
3 Jul 1861	Near Livermore		VIII
1 Oct 1865	Fort Humboldt-Eureka area		VIII-IX
8 Oct	Santa Cruz Mountains		VIII-IX
21 Oct 1868	Hayward		IX-X
26 Mar 1872	Near Lone Pine	Possibly 8+	X-XI
19 Apr 1892	Vacaville		IX
21 Apr	Winters		IX
4 Apr 1893	Northwest of Los Angeles		VIII-IX
20 Jun 1897	Near Hollister		VIII
14 Apr 1898	Mendocino area		VIII-IX
22 Jul 1899	San Bernardino County		VIII
25 Dec	San Jacinto-Hemet area		IX
27&31 Jul 1902	Santa Barbara County		VIII
18 Apr 1906	San Francisco region	8.3	XI
28 Apr	Brawley, Imperial Valley	6-6.9	VIII
28 Oct 1909	Humboldt County	6+	VIII
11 Jan 1915	Los Alamos		VIII
22 Jun	El Centro-Calexico-Mexicali area	6.25	VIII
21 Apr 1918	San Jacinto-Hemet area	6.8	IX
21 Jun 1920	Inglewood		VIII
10 Mar 1922	Cholame Valley	6.5	IX
29 Jun 1925	Santa Barbara area	6.3	VIII-IX
22 Oct 1926	Monterey Bay	6-6.9	VIII
20 Aug 1927	Humboldt Bay		VIII
4 Nov	West of Point Arguello	7.5	IX-X
25 Feb 1930	Westmorland	5.0	VIII
1 Mar	Brawley	4.5	VIII
6 Jun 1932	Humboldt County	6.4	VIII
10 Mar 1933	Near Long Beach	6.3	IX
7 Jun 1934	Parkfield	6.0	VIII
18 May 1940	Imperial Valley	7.1	X
30 Jun 1941	Santa Barbara-Carpinteria area	5.9	VIII
15 Mar 1946	North of Walker Pass	6.25	VIII
29 Jul 1950	Imperial Valley	5.5	VIII
21 Jul 1952	Arvin-Tehachapi	7.7	XI
22 Aug	Bakersfield	5.8	VIII
25 Apr 1954	East of Watsonville	5.25	VIII
21 Dec	Eureka	6.6	VII
12 Sep 1966	Truckee	6.6	VIII
8 Apr 1968	Northeast San Diego County	6.5	VII
1 Oct 1969	Santa Rosa	5.7	VII-VIII
9 Feb 1971	San Fernando	6.5	VIII-XI

*The Richter magnitude scale was not published until 1935. If values appear in this column for earthquakes which occurred prior to that date, the magnitudes were determined as follows: 1) if given to the nearest tenth, the records of older instruments were correlated with records of instruments now in use; 2) otherwise, historical records of intensity were used to estimate magnitude.

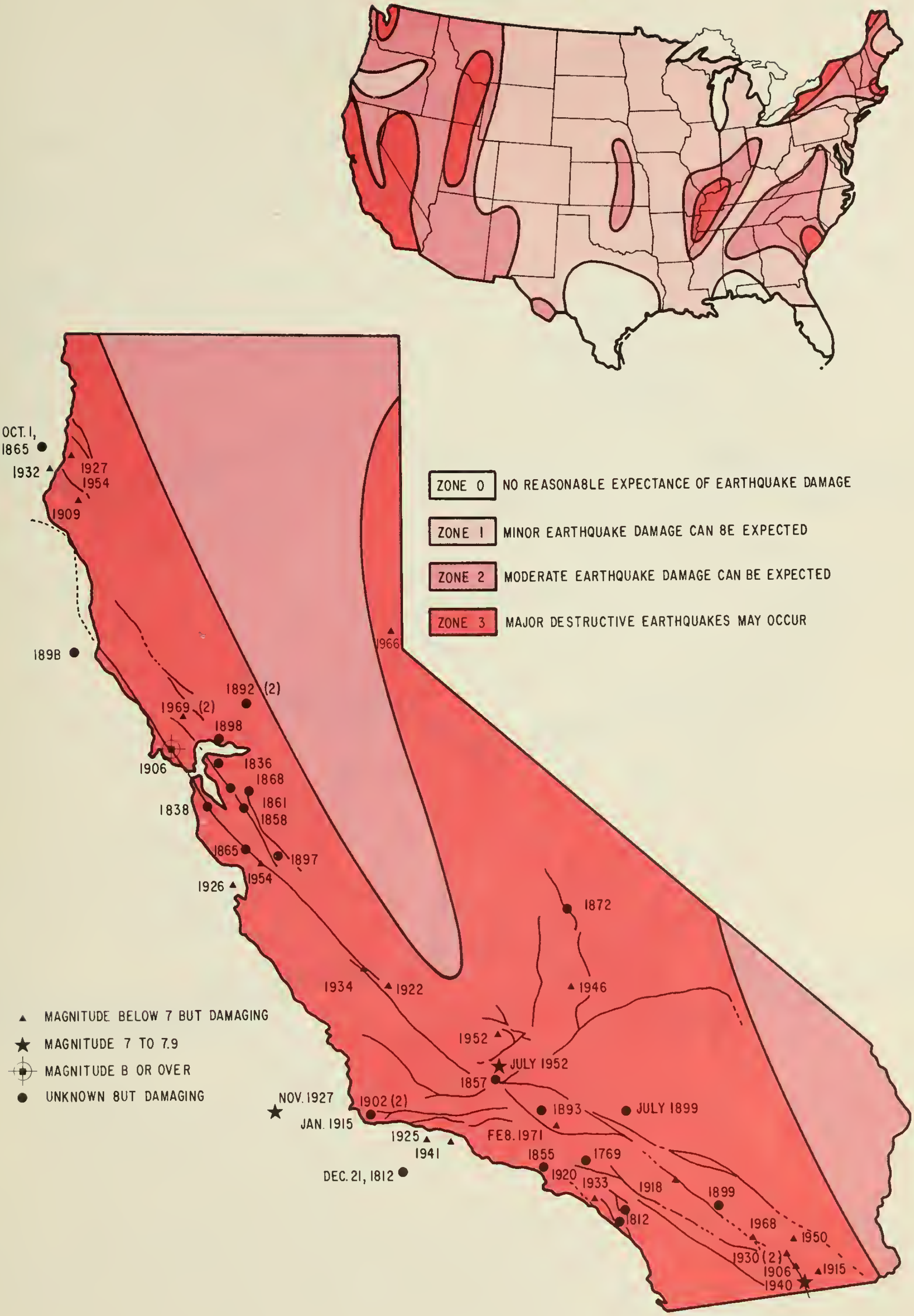


Figure 2. Seismic risk map for conterminous United States. The inset of California shows seismic risk zones, epicenters of the prominent earthquakes since 1769 as listed in the table, their magnitude when known, and the major faults of California. *From* Earthquake Information Bulletin, *March-April and May-June 1971.*

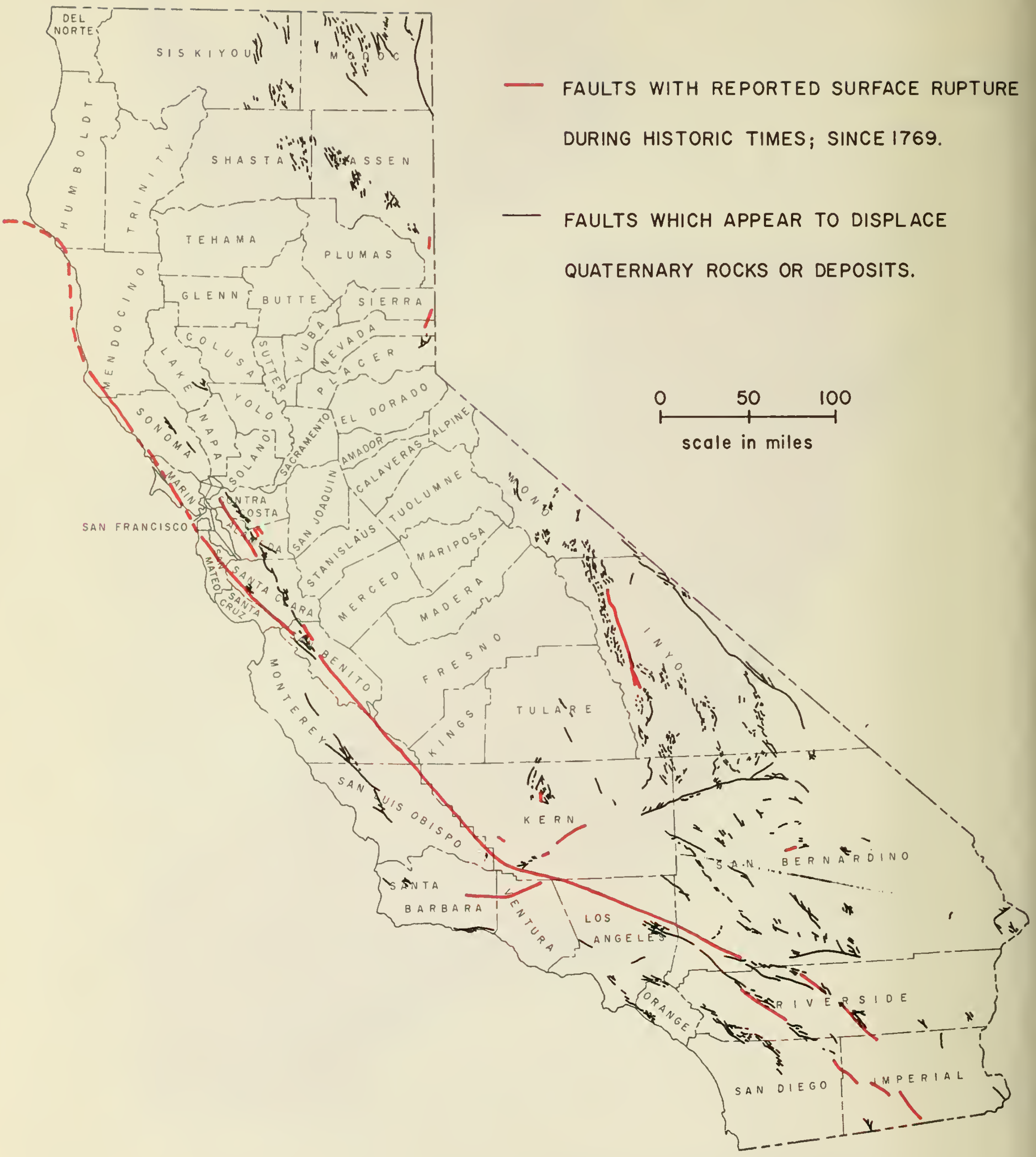


Figure 3. Fault-caused ground breakage which has occurred in California. *Modified after* CDMG Provisional Fault Map of California.

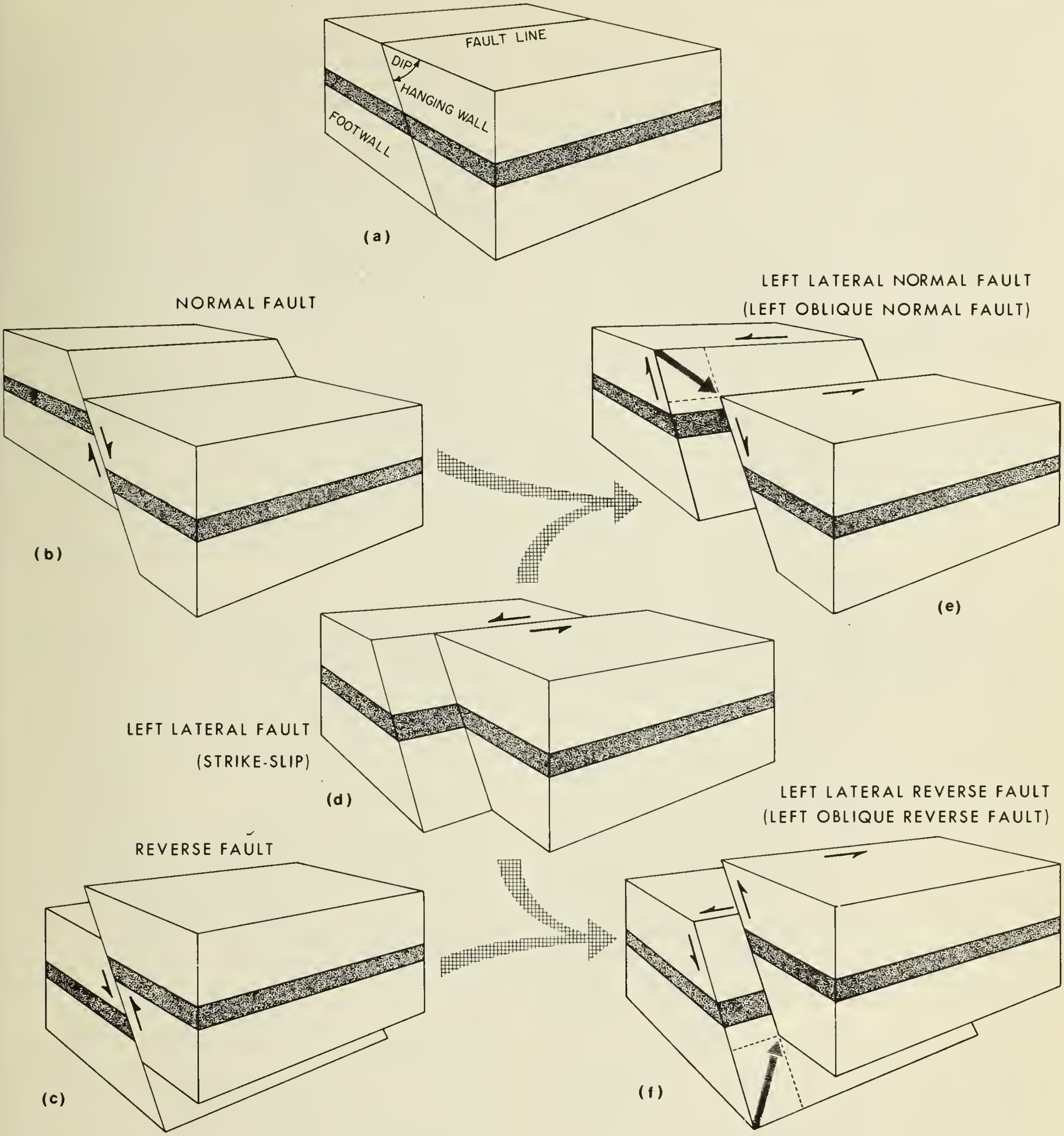


Figure 4. Types of fault movement. a) Names of some of the components of faults. b) Normal fault, in which the hanging wall has moved down relative to the foot wall. c) Reverse fault, sometimes called thrust fault, in which the hanging wall has moved up relative to the foot wall. d) Lateral fault, sometimes called strike-slip fault, in which the rocks on either side of the fault have moved sideways past each other. It is called *left* lateral if the rocks on the other side of the fault have moved to the left, as observed while facing the fault and *right* lateral if the rocks on the other side of the fault have moved to the right, as observed while facing the fault. e) Left lateral normal fault, sometimes called a left oblique normal fault. Movement of this type of fault is a combination of normal faulting and left lateral faulting. f) Left lateral reverse fault, sometimes called a left oblique reverse fault. Movement of this type is a combination of left lateral faulting and reverse faulting. Two types of faults not shown are similar to those shown in e and f. They are a *right* lateral normal fault and a *right* lateral reverse fault (a right oblique normal fault and a right oblique reverse fault, respectively).

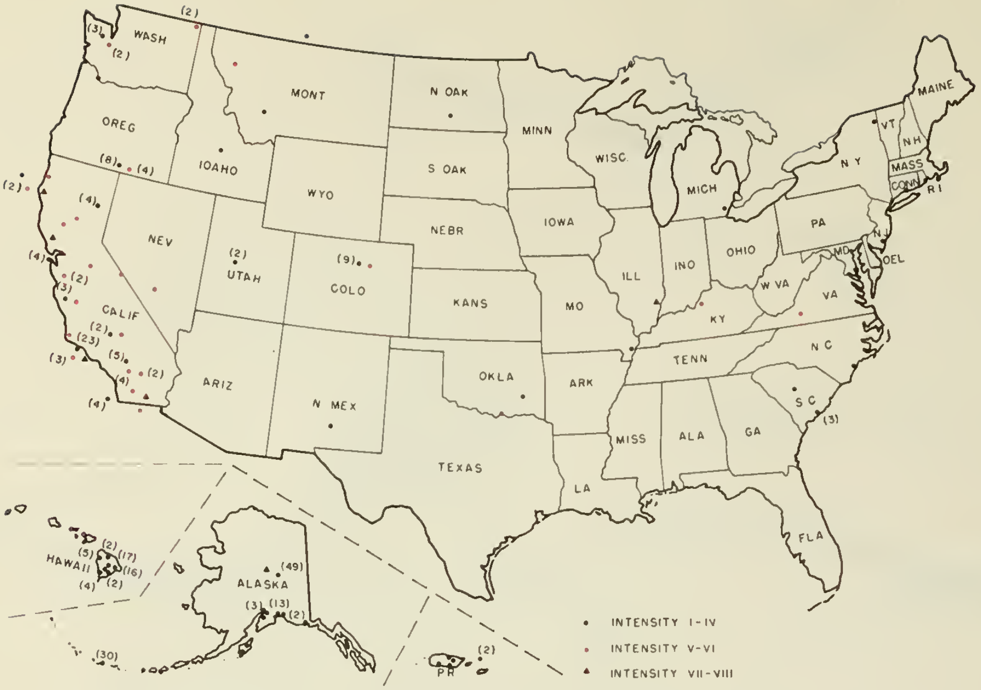


Figure 5. United States earthquake epicenters for 1968. The maximum Modified Mercalli intensity which was observed in the U. S. during 1968 earthquakes was VIII. Numerals beside a dot show the number of shocks which occurred at that location. Note the large number of events which took place in California as compared to the rest of the U.S.

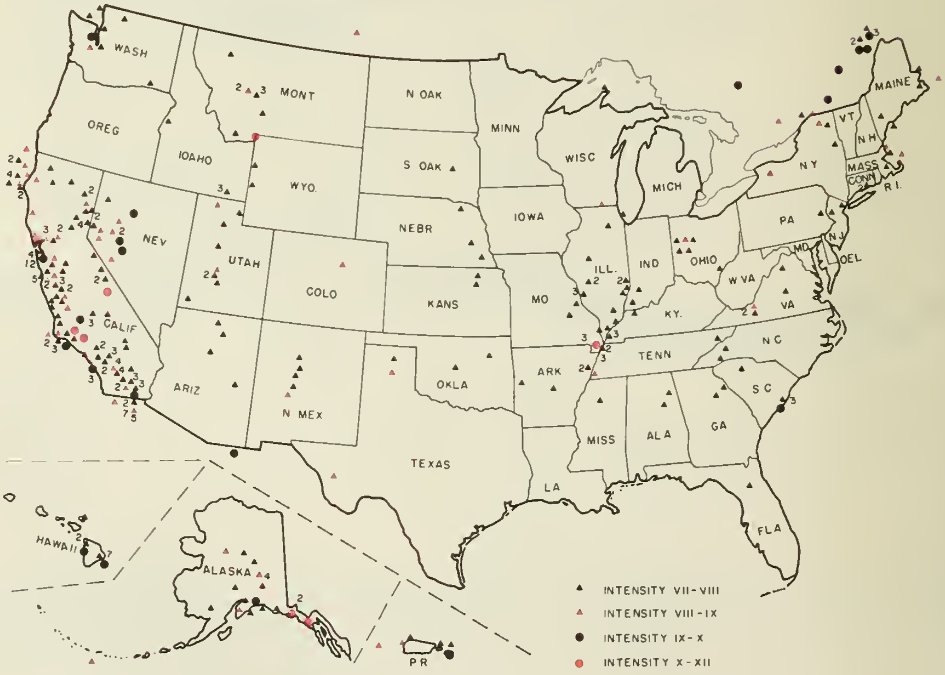


Figure 6. Damaging earthquakes in the United States, 1769 through 1968. Only epicenters of earthquakes that were of Modified Mercalli intensity VII and above are shown. If epicenters of lower intensity had been plotted on the map, many individual events that took place in California would be indistinguishable from each other. The numerals beside the dots show the number of shocks which occurred at each location. *Both Figure 5 and Figure 6 were taken from* United States Earthquakes 1968, *by Coffman and Cloud.*

world. We know that the frequency of earthquakes in the U. S. is going to be higher in the western states than elsewhere. Even more specifically, we know that the frequency of earthquakes in California is going to be highest along the faults that historically have been the most active. Therefore, it can be predicted that earthquakes will continue along the San Andreas fault, the San Jacinto fault, the Sierra Nevada fault, and the Hayward fault, among others. The San Fernando earthquake of 9 February 1971, however, was caused by crustal adjustments along a fault which was partly known but which was not considered to be particularly active. Obviously, then, *accurate* prediction of the location of future earthquakes is not yet possible.

We can also expect earthquakes to recur along these faults with at least the same magnitude that has been measured or estimated in the past, including earthquakes of both lesser and greater magnitude. The number of earthquakes for which the magnitude has been recorded is insufficient to allow reliable statistical determination of the probable maximum earthquake magnitude which can be expected along a given fault. To reiterate, then, we know we can expect large magnitude earthquakes where they have occurred before. Obviously, this is not an *accurate* prediction of magnitude.

The third parameter of prediction, the time of the earthquake, is subject to even fewer deductions than are the first two parameters. Earthquakes have occurred in the past and, as State Geologist Wesley G. Bruer says in the foreword to this article: “Knowledgeable earth scientists unanimously agree that California will periodically experience severe earthquakes long into the future.” Earthquakes will continue, but we don’t have the ability to forecast the month, much less the day and the hour. Obviously, this is not an *accurate* prediction of the time of an earthquake.

It may eventually be possible to predict accurately the time, the place and the magnitude of an impending earthquake, and, in addition, to predict where the ground will rupture. The map in figure 3 shows where the ground surface has been broken by the stresses of crustal adjustment during earthquakes since 1769. Hopefully, it will become possible to outline more accurately areas subject to such ground rupture.

In summary, it is not yet possible to predict accurately the location, the magnitude, or the time of future earthquakes even though we can make some very general deductions. Basic research into the causes, frequency, and ground movement of earthquakes is necessary if we ever expect to understand these phenomena well enough to be able to predict them accurately. Basic research techniques include measurement of the rate of creep of two fault blocks past each other, measurement of the amount of tilt the earth’s crust is undergoing, precise geodetic surveying and measurement of the amount of strain accumulating in the rocks of the crust, and measurement of vibratory ground motion during earthquakes. Laser beam ranging devices, tiltmeters, strain meters, seismographs and accelerographs are some of the instruments used to measure these changes. Colleges and universities in California, the U. S. Geological Survey, the National Oceanic and Atmospheric Administration, and the California Division of Mines and Geology all maintain active programs of basic earthquake research.

WHAT CAN BE DONE ?

The accurate prediction of earthquakes may be far in the future, but we can take some *immediate* steps to reduce the loss of life caused by earthquakes. Constant improvement of the standards for the design and construction of structures is required. Most communities use the Uniform Building Code to guide them in requiring that certain standards be followed in construction practices. The Uniform Building Code is excellent for this purpose. Nevertheless, as new data are provided by basic earthquake research, even the Uniform Building Code must be modified so that recently acquired earthquake engineering data can be incorporated to increase the earthquake safety of construction practices required by the Code.

The accumulated knowledge concerning earth movement during an earthquake is presently adequate to design substantially earthquake-resistant structures that would appreciably reduce both injuries and deaths and would minimize the cost of quake-caused damage. Public schools in California built under the constraints of the Field Act of 1933 have borne this out.

Most deaths and injuries in earthquakes have been caused by falling debris or the collapse of structures (see photographs). Other casualties have been caused by earthquake-triggered landslides, avalanches, fires, seismic sea waves (tsunamis), fallen power lines, and panic. Fault rupture or ground cracking itself seldom is the direct cause of death or injuries unless such ground cracking occurs under the foundation of a large building.

The initial damage to structures occurs during the first few seconds of the earthquake when the ground is accelerated suddenly. The frame of any building obviously must hold the roof and the floors of that building off the ground and must hold the walls of the building apart under normal conditions. Too many buildings, however, have been built without taking into account the additional strong horizontal and vertical forces likely to be exerted in a severe earthquake. This is particularly true of many older buildings but, some changes in the Uniform Building Code are necessary to ensure the survival of new buildings subjected to the accelerations experienced during a moderate earthquake.

Even if the building survives the initial accelerations of the ground, sustained shaking may cause gradual disintegration of the building’s components. The data gathered from the many instruments that operated during the San Fernando earthquake will go far in helping to improve the design of buildings so that they can withstand both the initial accelerations and the sustained shaking.

Not so surprisingly, one-story wood-frame houses have performed well in many earthquakes throughout the world, even when they have been subjected to high accelerations. This is because of the inherent flexibility of this type of structure.

Although there is no way to eliminate all earthquake dangers, injury and damage can be reduced substantially if the following steps are taken before, during, and after the quake.

Before an Earthquake

1. Potential earthquake hazards in the home should be removed or corrected. Top-heavy objects and furniture, such as bookcases and storage cabinets, should be fastened to the wall and the largest and heaviest objects placed on lower shelves. Water heaters and other appliances should be firmly bolted down, and flexible connections should be used whenever possible.

2. Supplies of food and water, a flashlight, a first aid kit, and a battery-powered radio should be set aside for use in emergencies. Of course, this is advisable for other types of emergencies, as well as for earthquakes.

3. One or more members of the family should have a knowledge of first aid procedures because medical facilities nearly always are overloaded during an emergency or disaster, or may themselves be damaged beyond use.

4. All responsible family members should know what to do to avoid injury and panic. They should know how to turn off the electricity, water, and gas; and they should know the locations of the main switch and valves. This is particularly important for teenagers who are likely to be alone with smaller children.

5. Programs that train policemen, firemen, and civil defense wardens how to perform effectively after an earthquake should be supported. One public agency should be designated as being responsible for organizing search-and-rescue activities. Studies of activity after the Good Friday earthquake in Alaska in 1964 concluded that people did what they had been trained to do. Firemen looked for fires to extinguish; policemen directed traffic and guarded against law violations; utility workers restored utilities; and administrators held meetings. A systematic search-and-rescue effort was not begun until 12 hours after the quake because no agency had direct and immediate responsibility for this activity.

6. Pre-Field Act schools, older buildings, public facilities, and dams that are not earthquake resistant should be replaced or strengthened. As an example, the City of Long Beach, with a combination of foresight and fortitude, has enacted and is enforcing a very effective code dealing with structurally sub-standard buildings. Overhangs, cornices, and parapets on buildings pose an extreme hazard to public safety and should be securely fastened to the buildings or removed.

7. It is most important for a resident of California to be aware that this is "earthquake country" and that earthquakes are most likely to occur again where they have occurred before. Building codes that require earthquake-resistant construction should be vigorously supported and, when enacted into law, should be rigorously enforced. If effective building codes and grading ordinances do not exist in your community, support their enactment.

8. Zoning ordinances should be enacted to limit the types of construction allowed in active fault zones.

9. Above the fourth or fifth floor in taller buildings, heavy objects such as desks, tables, and bookcases should be bolted or otherwise securely fastened to the floor or wall. Heavy furniture like this can become virtual battering rams under some conditions of earthquake shaking. Stout guard rails should be installed across windows which extend to the floor.

10. In new construction or in alterations of existing structures, building codes, if they exist, should be diligently followed to reduce and minimize potential hazards. Construction sites should be carefully selected, graded, and engineered to reduce all potential geologic hazards including landslides, subsidence, and the effects of earthquakes.

11. Public safety agencies in your community should have reliable auxiliary communication equipment that can be operated during periods of emergency when regular power supplies may be interrupted.

12. Research to learn more about earthquakes, matching site selection to intended use, and construction of resistant structures should be strongly supported. In the home, at work, or at any other place, you should give some thought to what you would do in the event of an earthquake. Planning ahead may enable you to react effectively during such an emergency.

During an Earthquake

The most important thing to do during an earthquake is to remain calm. If you can do so, you are less likely to be injured. If you are calm, those around you will have a greater tendency to stay calm, too. Make no moves or take no action without thinking about the possible consequences. Motion during an earthquake is not constant; commonly, there are a few seconds between tremors.

1. If you are inside a building, stand in a strong doorway or get under a desk, table, or bed. Watch for falling plaster, bricks, light fixtures, and other objects. Stay away from tall furniture, such as china cabinets, bookcases, and shelves. Stay away from windows, mirrors, and chimneys. In tall buildings, it is best to get under a desk if it is securely fastened to the floor, and to stay away from windows or glass partitions.

2. Do not rush outside. Stairways and exits may be broken or may become jammed with people. Power for elevators and escalators may have failed. Many of the 115 persons who perished in Long Beach and Compton in 1933 ran outside only to be killed by falling debris and collapsing chimneys. If you are in a crowded place such as a theater, athletic stadium, or store, do not rush for an exit because many others will do the same thing. If you must leave a building, choose your exit with care and, when going out, take care to avoid falling debris and collapsing walls or chimneys.

3. If you are outside when an earthquake strikes, try to stay away from high buildings, walls, power poles, lamp posts, or other structures that may fall. Falling or fallen electrical power lines must be avoided. If possible, go to an open area away from all hazards but do not run through the streets. If you are in an automobile, stop in the safest possible place, which, of course, would be an open area, and remain in the car.

After an Earthquake

1. After an earthquake, the most important thing to do is to check for injuries in your family and in the neighborhood. Seriously injured persons should not be moved unless they are in immediate danger of further injury. First aid should be administered, but only by someone who is qualified.

2. Check for fires and fire hazards. If damage has been severe, water lines to hydrants, telephone lines, and fire alarm systems may have been broken; contacting the fire department may be difficult. Some cities, such as San

Francisco, have auxiliary water systems and large cisterns in addition to the regular system that supplies water to fire hydrants. Swimming pools, creeks, lakes, and fish ponds are possible emergency sources of water for fire fighting.

3. Utility lines to your house--gas, water, and electricity--and appliances should be checked for damage. If there are gas leaks, shut off the main valve which is usually at the gas meter. Do not use matches, lighters, or open-flame appliances until you are sure there are no gas leaks. Do not use electrical switches or appliances if there are gas leaks, because they give off sparks which could ignite the gas. Shut off the electrical power if there is damage to the wiring; the main switch usually is in or next to the main fuse or circuit breaker box. Spilled flammable fluids, medicines, drugs, and other harmful substances should be cleaned up as soon as possible.

4. Water lines may be damaged to such an extent that the water may be off. Emergency drinking water can be obtained from water heaters, toilet tanks, canned fruits and vegetables, and melted ice cubes. Toilets should not be flushed until both the incoming water lines and outgoing sewer lines have been checked to see if they are open. If electrical power is off for any length of time, plan to use the foods in your refrigerator and freezer first before they are spoiled. Canned and dried foods should be saved until last.

5. There may be much shattered glass and other debris in the area, so it is advisable to wear shoes or boots and a hard hat if you own one. Broken glass may get into foods and drinks. Liquids can be either strained through a clean cloth such as a handkerchief or decanted. Fireplaces, portable stoves, or barbecues can be used for emergency cooking but the fireplace chimney should be carefully checked for cracks and other damages before being used. In checking the chimney for damage, it should be approached cautiously, because weakened chimneys may collapse with the slightest of aftershocks. Particular checks should be made of the roof line and in the attic because unnoticed damage can lead to a fire. Closets and other storage areas should be checked for objects that have been dislodged or have fallen, but the doors should be opened carefully because of objects that may have fallen against them.

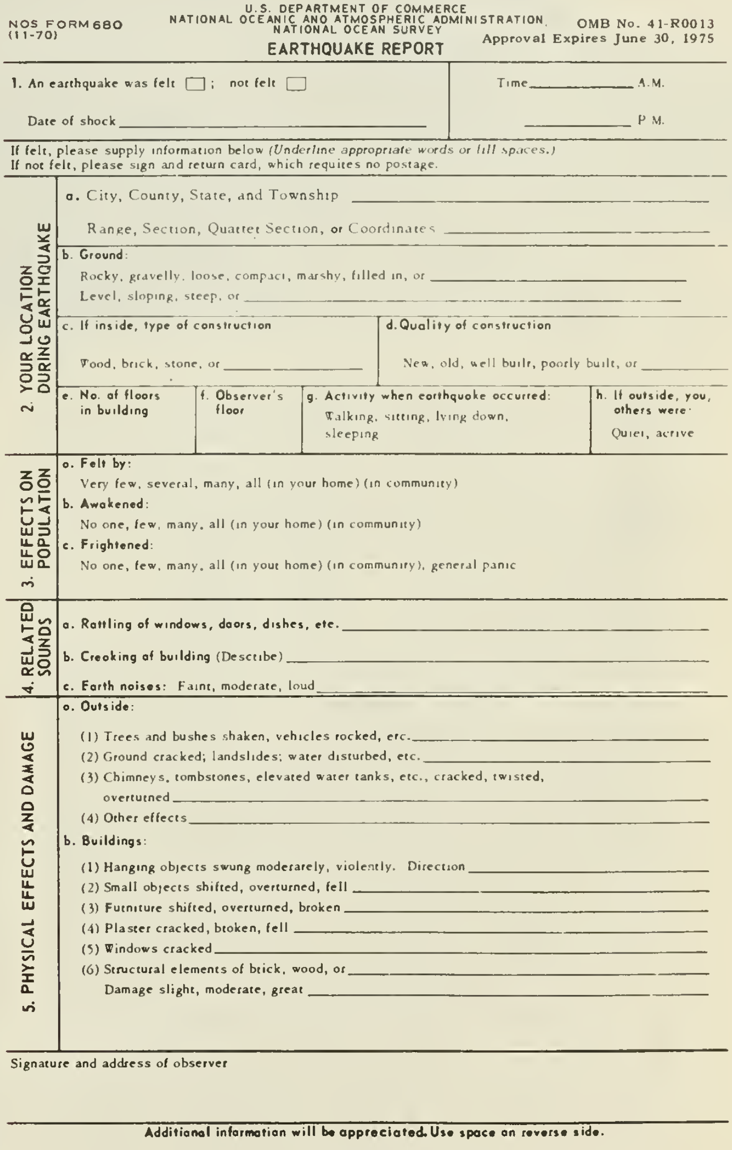
6. Do not use the telephone unless there is a genuine emergency. Emergencies, and damage reports, alerts, and other information can be obtained by turning on your radio. Do not go sightseeing; keep the streets open for the passage of emergency vehicles and equipment. Do not speculate or repeat the speculations of others--this is how rumors start.

7. Stay away from beaches and other waterfront areas where seismic sea waves (tsunamis), sometimes called "tidal waves", could strike. Again, your radio is the best source of information concerning the likelihood that a seismic sea wave will occur. Also stay away from steep landslide-prone areas if possible, because aftershocks may trigger a landslide or avalanche, especially if there has been a lot of rain and the ground is nearly saturated. Also stay away from earthquake-damaged structures. Additional earthquake shocks known as "aftershocks" normally occur after the main shock, sometimes over a period of several months. These are usually smaller than the main shock but they can cause damage, too, particularly to damaged and already weakened structures.

8. Parents should stay with young children who may suffer psychological trauma if parents are absent during the occurrence of aftershocks.

9. Cooperate with all public safety and relief organizations. Do not go into damaged areas unless authorized; you are subject to arrest if you get in the way of, or otherwise hinder, rescue operations. Martial law has been declared in a number of earthquake disasters. In the 1906 disaster in San Francisco, several looters were shot.

10. Send information about the earthquake to the Seismological Field Survey (see figure 7) to help earth scientists understand earthquakes better.



NOS FORM 680
(11-70)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY
EARTHQUAKE REPORT

OMB No. 41-R0013
Approval Expires June 30, 1975

1. An earthquake was felt ☐; not felt ☐

Date of shock ____

Time ____ A.M.

____ P.M.

If felt, please supply information below *(Underline appropriate words or fill spaces.)*
If not felt, please sign and return card, which requires no postage.

2. YOUR LOCATION DURING EARTHQUAKE

a. City, County, State, and Township ____

Range, Section, Quarter Section, or Coordinates ____

b. Ground:

Rocky, gravelly, loose, compact, marshy, filled in, or ____

Level, sloping, steep, or ____

c. If inside, type of construction

Wood, brick, stone, or ____

d. Quality of construction

New, old, well built, poorly built, or ____

e. No. of floors in building

f. Observer's floor

g. Activity when earthquake occurred:

Walking, sitting, lying down, sleeping

h. If outside, you, others were:

Quiet, active

3. EFFECTS ON POPULATION

a. Felt by:

Very few, several, many, all (in your home) (in community)

b. Awakened:

No one, few, many, all (in your home) (in community)

c. Frightened:

No one, few, many, all (in your home) (in community), general panic

4. RELATED SOUNDS

a. Rattling of windows, doors, dishes, etc. ____

b. Creaking of building (Describe) ____

c. Earth noises: Faint, moderate, loud ____

5. PHYSICAL EFFECTS AND DAMAGE

a. Outside:

(1) Trees and bushes shaken, vehicles rocked, etc. ____

(2) Ground cracked; landslides; water disturbed, etc. ____

(3) Chimneys, tombstones, elevated water tanks, etc., cracked, twisted, overturned ____

(4) Other effects ____

b. Buildings:

(1) Hanging objects swung moderately, violently. Direction ____

(2) Small objects shifted, overturned, fell ____

(3) Furniture shifted, overturned, broken ____

(4) Plaster cracked, broken, fell ____

(5) Windows cracked ____

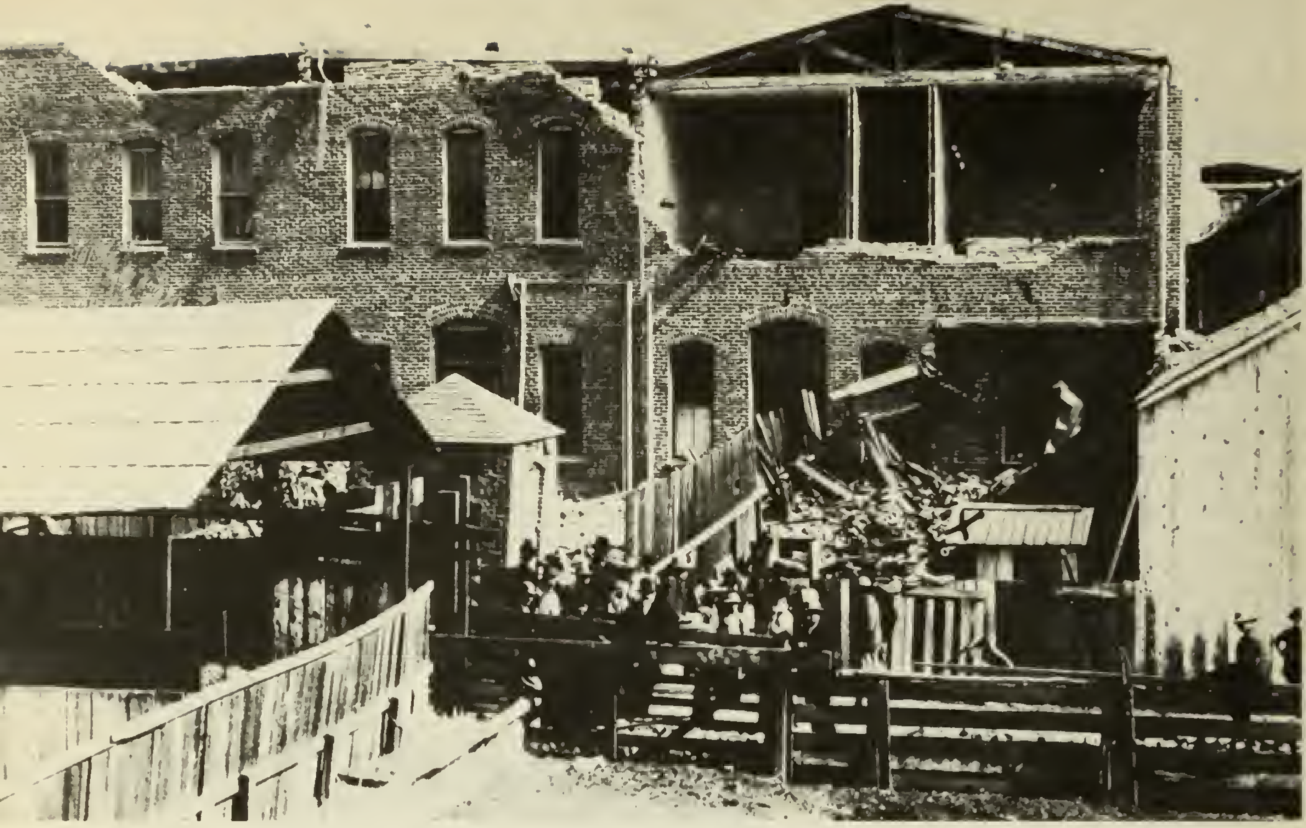
(6) Structural elements of brick, wood, or ____

Damage slight, moderate, great ____

Signature and address of observer

Additional information will be appreciated. Use space on reverse side.

Figure 7. The "Earthquake Report" sent out after an earthquake by the Seismological Field Survey to gather data that will help to better define seismic risk zones throughout the U. S. If you experience an earthquake, the earth scientists of the Seismological Field Survey will appreciate receiving the information asked for on this card. The data you provide will supplement instrumental data and will lead to a better understanding of earthquakes. Send your information to: Seismological Field Survey, NOAA, 390 Main Street, Room 7067, San Francisco, CA 94105.



Damage to the unreinforced brick walls of this hotel in Winters was caused by the Vacaville-Winters earthquake of 1892. Note the pile of bricks, rubble, and other debris just outside the door in right center. The part of the hotel on the left in this picture is still in use today. The main street of Winters is just beyond the hotel. *Photo courtesy of Ralph G. Scott and Roger W. Greensfelder.*

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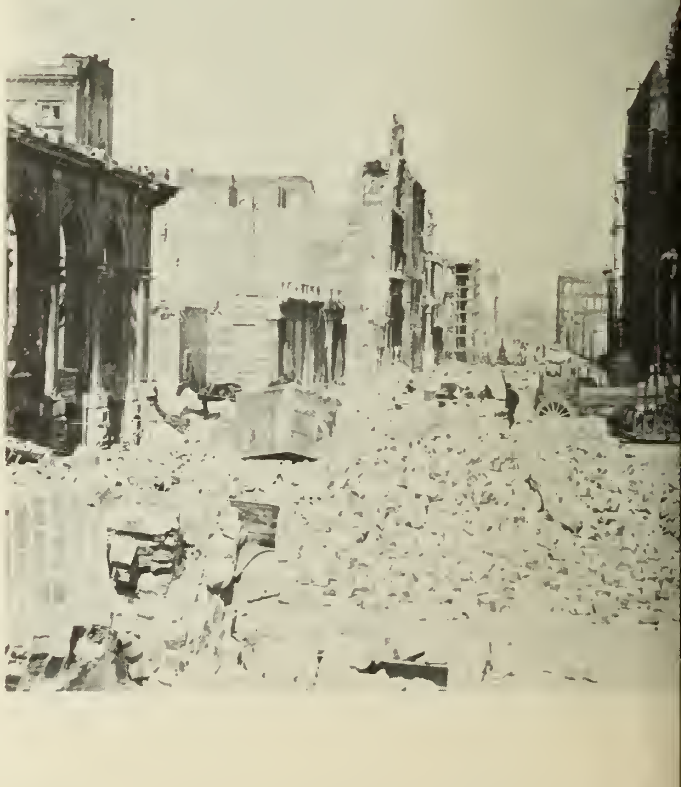
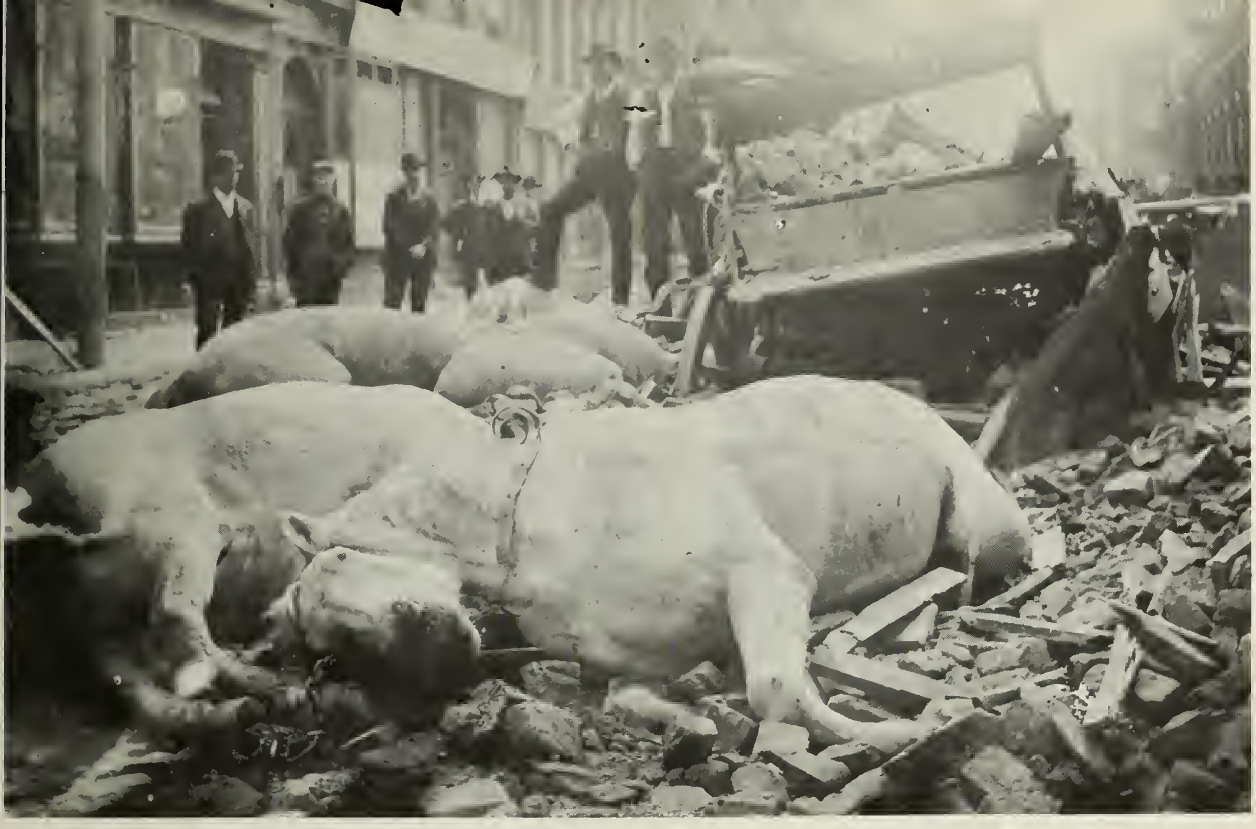
U. S. Geological Survey and Office of Emergency Preparedness, 1969, Safety and survival in an earthquake: Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402. Price 10 cents.

Additional information about earthquakes may be obtained from the following sources:

1. Local library.
2. California Division of Mines and Geology.
3. National Ocean Survey
4. U. S. Geological Survey.

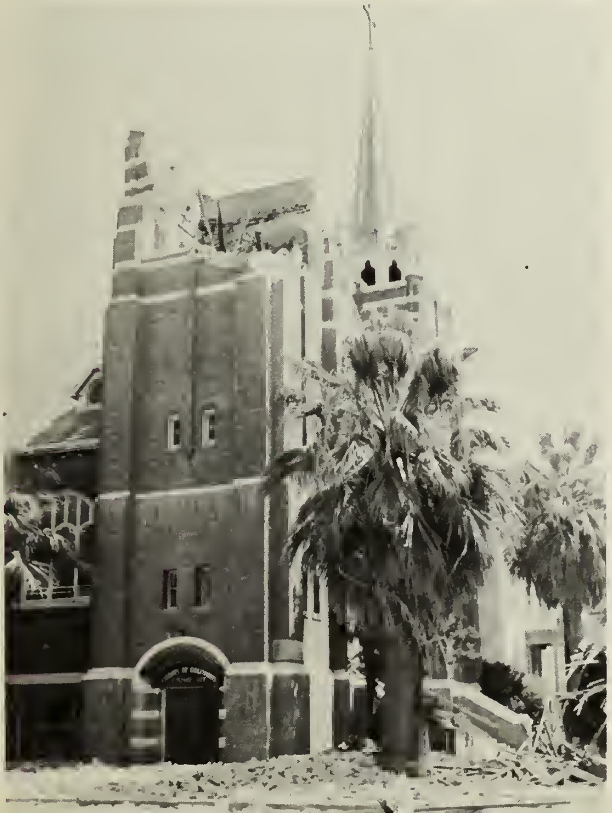
Bricks, concrete, and other debris on a street of San Francisco after the earthquake of 1906. Unreinforced brick walls of most of the buildings in this view appear to have been totally destroyed. The stone facades of several of the buildings remained standing. This view is east toward Market Street. *Photo courtesy of Eric Swenson.*

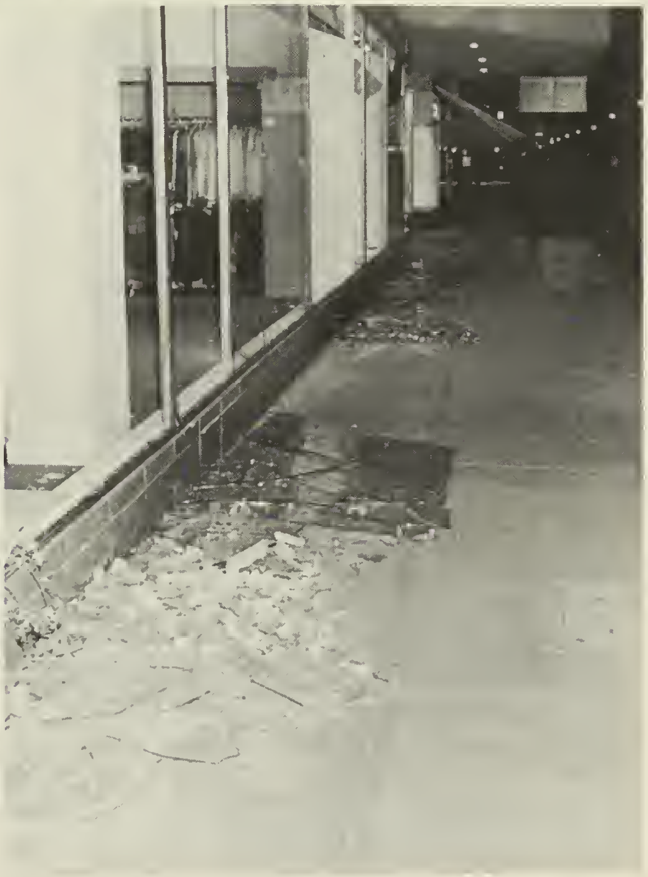




Horses apparently killed by falling debris during the San Francisco earthquake of 1906. The wagon also was crushed by falling masonry. *Photo courtesy of Eric Swenson.*

Damaged church in Bakersfield after the Arvin-Tehachapi earthquake of 21 July 1952 and the severe aftershock of 22 August near Bakersfield. Movement which caused the earthquakes took place along the White Wolf fault, which had been considered "inactive" until 1952. Note that the bricks, rubble, and other debris fell mostly on the sidewalk close to the building itself, and in front of the exits. *Photo by Seismological Field Survey.*





Damage caused by Santa Rosa earthquake of 1 October 1969. Plate glass windows from the first floor of this store broke and fell to the sidewalk as a result of earth movement during the quake. Many modern high-rise buildings have plate glass windows up to the topmost floor. *Photo courtesy of Santa Rosa Press Democrat.*

Picture taken after t
earthquake. The am
considerably after t
stairs in the fire esc
with rubble to drop
Note how the rubbl
escape route. *Phot*

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tric clinic at the Olive View Hospital near San
his building was originally a two story building but
ement during the San Fernando earthquake of 9
'1 caused the first story to collapse, bringing the
down to ground level. Had the quake struck later in
ing business hours, the offices on the first floor
contained many people and the death toll of the
obviously have been much higher. *Photo by James*

EAR

The followir
of an earthquak
reference.

BEFORE

1. Store
flashlight and b
2. Take
3. Locate main switches and valves
flow of water, gas, and electricity into your house. Know how to operate them.
4. Support community programs that inform the public and emergency personnel about earthquake preparedness.
5. Take action to help strengthen or eliminate structures that are not earthquake-resistant.
6. Support "parapet ordinances" that would remove dangerous, unreinforced overhangs and cornices from buildings.
7. Support building codes that require earthquake-resistant construction and careful foundation preparation and grading.
8. Support land use policies that recognize and allow for the potential dangers of active fault zones.
9. Heavy furniture above the fifth floor in tall buildings should be bolted to the floor.
10. Require guard rails across the inside of plate glass windows that extend to the floor.
11. Support basic research into the cause and mechanism of earthquakes and fault movement.

't panic even if you are frightened.
ou are indoors, stay there. Get under a desk,
orway.
not rush outside. Falling debris has caused many

ch for falling plaster, bricks, and other objects.
you are outside, move away from buildings and
wer lines; stay in the open.
6. If you are in a moving car, stop as soon as it is safe.
main in the car.

AFTER

1. Check your family, or the people near you for injuries.
2. Inspect your utilities for damage to water, gas, or electrical conduits. If they are damaged, turn them off.
3. Extinguish open flames.
4. Do not use the telephone except to report an emergency.
5. Turn on your battery-powered radio for emergency information.
6. Don't go sightseeing.
7. Stay away from damaged structures; aftershocks can cause the collapse of weakened structures.
8. Stay away from beaches and waterfront areas subject to seismic sea waves (commonly called "tidal waves").

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